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CHEMICAL BIOLOGICAL CENTER

U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND

ECBC-TR-047

**TESTS OF LEVEL B SUITS – PROTECTION AGAINST
CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND
SIMULANTS: EXECUTIVE SUMMARY**

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July 1999

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1999092 005



Aberdeen Proving Ground, MD 21010-5424

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE July 1999	3. REPORT TYPE AND DATES COVERED Final; 98 Jan - 98 Jun	
4. TITLE AND SUBTITLE Tests of Level B Suits – Protection Against Chemical and Biological Warfare Agents and Simulants: Executive Summary		5. FUNDING NUMBERS None	
6. AUTHOR(S) Lindsay, Robert S.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) DIR, ECBC*, ATTN: AMSSB-REN, APG, MD 21010-5424		8. PERFORMING ORGANIZATION REPORT NUMBER ECBC-TR- 047	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) CDR, SBCCOM*, ATTN: AMSSB-ODP, APG, MD 21010-5424		10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES <i>*When the work was conducted, the U.S. Army Edgewood Chemical Biological Center (ECBC) was known as the U.S. Army Edgewood Research, Development and Engineering Center (ERDEC); and the U.S. Army Soldier and Biological Chemical Command (SBCCOM) was known as the U.S. Army Chemical and Biological Defense Command (CBDCCOM).</i>			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Six Level B protective suits were tested for GB and HD permeation swatch testing using modified procedures of TOP 8-2-501. Agent break-through times were calculated for each suit. Aerosol agent simulant tests of suit systems were conducted to measure overall protection factors of the suits.			
14. SUBJECT TERMS HD Swatch testing Chemical protective suits GB Permeation testing Aerosol testing		15. NUMBER OF PAGES 12	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

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Executive Summary

As part of the Domestic Preparedness Program, six Occupational Safety and Health Level B* suit designs were tested to assess their capability to protect in a CW agent or biological agent environment. Swatches of material from each suit design were tested for resistance to permeation for Sarin (GB) and mustard agent (HD). From this data, the authors calculated the estimated time it would take to permeate the suit with sufficient agent to cause physiological effects in a person wearing the suit. Each suit design was also tested for its protection factor in an aerosol environment (aerosolized corn oil, which may be representative of a chemical or biological agent, was used). Protection factor is defined as the ratio between the challenge concentration outside the suit and the measured concentration inside the suit. The tests are described, and the calculated breakthrough times and overall protection factors are presented.

* Level B protection consists of chemical-resistant clothing (overalls and long-sleeved jacket; hooded one- or two-piece chemical splash suit; disposable chemical-resistant one-piece suit), inner and outer gloves, chemical-resistant safety boots and hard hat with pressure-demand full-facepiece SCBA or pressure-demand supplied-air respirator with escape SCBA. Level B, rather than Level A, protection is used when a high level of respiratory protection is required but less skin protection is needed.

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Preface

The work described herein was authorized under the Expert Assistance (Equipment Test) Program for the U. S. Army Chemical and Biological Defense Command (CBDCOM)* Program Director for Domestic Preparedness.

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* Now known as the U.S. Army Soldier Biological Chemical Command (SBCCOM).

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TESTS OF LEVEL B SUITS – PROTECTION AGAINST CHEMICAL AND BIOLOGICAL WARFARE AGENTS AND SIMULANTS: EXECUTIVE SUMMARY

1. INTRODUCTION

In 1996, responding to Public Law 104 - 201, the Department of Defense (DoD) formed the Domestic Preparedness Program. One of the objectives was to enhance federal, state, and local capabilities to respond to nuclear, biological, and chemical (NBC) terrorism incidents. In some cases, people who respond to an incident will use Occupational Safety and Health Administration (OSHA) Level B protective suits to enter a contaminated or potentially contaminated area. Limited data was available concerning the effectiveness of commercially available OSHA Level B suits as protection against chemical warfare (CW) agents. Recognizing this need, the U.S. Army Chemical and Biological Defense Command (CBDCOM)* established a program to test some of the Level B suit designs, using CW agents and test procedures developed for assessment of military-issue CW protective equipment. A detailed technical report was generated for each suit design tested, and a summary report was prepared that presented the essential results for all the suits in a single document. Because those reports are rather lengthy and technical, this report was prepared. This report is an overview of the results of the evaluation and is intended primarily for emergency response organizations and managers, to aid them in making informed decisions when evaluating suit replacements.

The suits and suit materials were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors were beyond the scope of this test program. The OSHA Level B suits are chemical-resistant clothing that protect the wearer from liquid chemicals. Air is supplied by a pressure-demand full-facepiece self-contained breathing apparatus (SCBA) or pressure-demand supplied-air respirator with escape SCBA. These tests addressed skin protection only and not the air supply system.

Each suit was examined in two different ways, called swatch tests and aerosol tests. In the swatch tests, sample swatches were cut from selected areas (the basic suit material, a suit seam, and four other areas that were dependent upon the suit configuration) of each suit design. These swatches were then exposed to the chemical agents mustard (HD) and sarin (GB), and the passage of agent through them measured. Sarin is a non-persistent (volatile) nerve agent, and HD is a persistent blister agent. In the aerosol tests, each suit design was donned by volunteer testers, who carried out a prescribed sequence of movements inside a test chamber containing a controlled aerosol of corn oil that is a non-toxic simulant for chemical and biological agent aerosols. Instrumentation continuously measured the concentration of simulant inside the suit. Each of these tests examined different aspects of the protection provided by the suits.

Protection provided by a suit system may vary from one unit to another, partly because variations in body size and shape affect the suit's fit; and from one occasion to another,

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partly because of unavoidable differences in the execution of the prescribed movements. For these reasons, each suit system design was subjected to multiple test repetitions, using a number of different sample suits, volunteer testers, and occasions.

2. LIQUID CHALLENGE/VAPOR PENETRATION TEST (SWATCH TEST)

For each suit design under test, six swatches (three to be tested with GB and three with HD) were taken from each of six different areas of the suit – 36 total swatches per suit design (with the exception of the MSA Blue Max suits, where only five areas were sampled to yield 30 total swatches). The swatches were placed in a test fixture and a predetermined (very severe) liquid agent challenge, GB or HD, was applied to the top surface of each swatch, and the fixture sealed. Periodically, over 24 hr, gas samples were taken from below the swatches. The amount of agent vapor that had passed through the test swatch at each sampling time was measured using a highly sensitive, accurate, miniaturized gas chromatograph and sampling system known as MINICAMS.

The cumulative mass of agent, which has passed through each of the swatches at each sampling time, divided by the area of the swatch, is defined as the permeation, M_f . Permeation is dependent on the test fixture and procedures used, as well as the properties of the agent and the swatch.

The permeation for each area of the suit tested was compared with other areas and other suit designs. Normally, continuous exposure to chemical agent would not exceed 8 hr (480 min) because of heat stress and fatigue, so the permeation, which occurs in the subsequent 16 hr, is of less interest.

The permeation will typically vary greatly from one area of a suit to the next, because of differences in materials and thickness. A composite average permeation value was calculated by assigning a weighting factor to the permeation value for each swatch, roughly proportional to the actual area on the suit system that the swatch represents. This resulted in a calculated overall permeation for each suit design.

Mustard vapor can produce skin irritation (erythema) at dosages (product of concentration and exposure time) of approximately 100 mg-min/cm^3 . Sarin vapor can produce incapacitation at dosages of approximately 8000 mg-min/m^3 . These dosages were set as limits, and the average time to reach each of the limits was calculated using the weighted values of the swatch test results, and it was designated the "breakthrough time" for the suit, under the specific test conditions.

The calculated breakthrough times from all the suit swatches are collected and presented in Table 1.

Table 1. Swatch Test Results for Level B Suits

Item	Breakthrough time, minutes	
	GB	HD
MSA Blue Max Model B	181	275
Lakeland Tychem 9400 Coverall - 94150	290	298
Kappler CPF3 Coverall 3T436	220	97
MarMac Tyvek/Saranex 23-P Coverall	178	54
ILC Dover Model 16-51 Coverall	110	42
Trellborg Splash 700 – 1 Piece Suit	46	44

3. SYSTEM TEST (AEROSOL SIMULANT)

This test measures the leakage of corn-oil aerosol (physical simulant for biological aerosols) into a suit ensemble. In this test, a volunteer tester donned an ensemble of a suit design (using a SCBA). The tester then entered the test chamber that contained a controlled concentration of aerosolized corn oil. The tester performed prescribed exercises in the test chamber, while low-volume air samples were taken from within the suit at the neck and upper arm and the corn-oil concentrations recorded continuously.

Eight different suits of each design were available in a range of sizes to fit the volunteer testers who participated in the test. A total of at least 22 test runs using at least 10 different testers, were completed for each suit design. During the test run, the tester performed each of the eight pre-operational exercises for 1 min and each of the eight operational exercises for 4 min. See Table 2. The total exposure/exercise time for each complete test run was therefore 40 min (8×1) + (8×4) = 40).

Table 2. Aerosol Test Exercise Routine

Phase of Test	Description of Exercise
Phase 1 (Pre-Operational) – Each exercise performed for 1 min.	1) Standing still, normal breathing 2) Bending forward and touching toes 3) Jogging in place 4) Raising arms above head and looking upward 5) Bending knees and squatting 6) Crawling on hands and knees 7) Torso twists with hands folded on chest 8) Standing still, normal breathing
Phase 2 (Operational) – Each exercise performed for 4 min.	1) Climb step ladder 2) Move 3-lb boxes from table to floor 3) Rest 4) Roll walls and ceiling with paint roller 5) Bag clothes 6) Rest 7) Loosen bolts 8) Move 3-lb boxes from floor to table

The corn-oil concentration measurements from within the suit, along with the known concentration of corn-oil aerosol in the test chamber, is used to calculate the protection factor (PF) of the suit ensemble for the test conditions. Essentially, PF is a measure of the reduction in cumulative exposure to the aerosol afforded by the suit. A higher percentage of suits that pass at higher PFs mean better protection.

The PF for an ensemble design is affected by the fit of the suit, the design of its seals and closures, and the amount of air exhaled by the wearer during the test. The results for a given suit design often vary widely from one test run to the next, the calculated values of PF for each suit design are compared to some PF values of interest (10, 50, 100) to make the distribution of results more apparent. Also, because the PF is often affected greatly by the tester's movements, the two parts of each test run are analyzed and presented separately. These data were compiled and summarized for all the actual suit designs in Table 3. One suit used in the study had quality problems due to tearing of the material during testing. Five out of eight MarMac Manufacturing Company (McBee, SC) Tyvek/Saranex suits tore. The material tore at the crotch and underarm area; generally at the stitched seams. In the author's opinion, the suits were inaccurately sized (too small), which contributed to the suits tearing. The suits were repaired with duct tape and used for the remainder of the aerosol testing. No other suits worn in the study experienced tearing.

Table 3. Summary of Overall Aerosol Test Results

Item	Percentage of Test Runs Where PF Met Each Hypothetical PF Threshold Value					
	10		50		100	
	Pre-Operational	Operational	Pre-Operational	Operational	Pre-Operational	Operational
MSA Blue Max Model B	0.0	0.0	0.0	0.0	0.0	0.0
Lakeland Tychem 9400 Coverall - 91450	0.0	0.0	0.0	0.0	0.0	0.0
Kappler CPF3 Coverall 3T436	0.0	0.0	0.0	0.0	0.0	0.0
MarMac Tyvek/Saranex 23-P Coverall	0.0	0.0	0.0	0.0	0.0	0.0
ILC Dover Model 16-51 Coverall	0.0	0.0	0.0	0.0	0.0	0.0
Trellborg Splash 700 – 1 Piece Suit	41.7	16.7	0.0	0.0	0.0	0.0

4. CONCLUSIONS AND RECOMMENDATIONS

The test data reveals that the Occupational Safety and Health Administration (OSHA) Level B suits tested can protect the wearers from liquid CW agents but only provide minimal protection from a vapor or aerosol threat. In other words, the OSHA Level B suit material does provide limited skin protection, but the suit itself provides little or no skin protection. Therefore, these OSHA Level B suits are not recommended for use where either vapor or aerosolized CW agents may be present.

The MarMac Tyvek/Saranex suit experienced significant tearing at the seams during aerosol testing. Recommend that the manufacturer reinforce the suit material to prevent future tearing.